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THE NEPHELITE SYENITE AND NEPHELITE PORPHYRY OF BEEMERVILLE, NEW JERSEY

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OUTLINE

INTRODUCTION

During the earlier geological survey of New Jersey many outcrops of igneous rocks, mainly dykes, were mapped and recorded in the state reports without particular description. These rocks are nearly all located in Sussex County, and, owing to the small size of most of the outcrops, their scattered nature, the maturity of the topography, and the extent of weathering of the rocks themselves, their interesting nature has only been recognized gradually, though the first record of the largest mass dates back to 1868.

Through the work of Emerson, Kemp, and Wolff these rocks are now widely known and are regarded in the local sense as a suite of genetically connected alkalic intrusions, and more generally as

showing affinity with the rocks of a dominantly sodic zone or comagmatic region which finds expression in the eastern United States from New England to Texas.[1]

The large mass of nephelite syenite situated to the northwest of Beemerville was first described in detail by Emerson, who recognized its true character and described it microscopically. He believed the mass to be a large dyke.[2] Emerson also described, under the name of mica-diabase, the series of dykes penetrating the ore-bodies at the Buckwheat Field at Franklin Furnace.[3]

Kemp examined the mass known as Rutan's Hill, which forms a prominent landmark east of the northern end of the main mass of nephelite syenite at Beemerville, and described it as a boss of porphyrite, giving two analyses of the rock, and one of the biotite isolated from it.[4] He also recognized the nature of a number of similar "bosses" to the southeast of the main mass, south of Beemerville and Plumbstock. On a more detailed investigation Kemp mapped and described the main mass and its immediate satellites, demonstrating clearly the inhomogeneity of the Beemerville nephelite syenite and proving the occurrence of a nephelite porphyry, probably as a dyke, within it. Here also he showed that the satellitic bosses are basic alkalic rocks, allied to the ouachitites and fourchites. He provided two analyses of different facies of the nephelite syenite and one of the nephelite porphyry.[5] These investigations established the fact that the Beemerville mass and its associates resemble the rocks of the Magnet Cove complex, Arkansas.

Kemp next examined a basic dyke two miles northwest of Hamburg, and from microscopical investigation, and the analysis of certain pseudomorphous spheroids which it exhibited, he offered the tentative suggestion that the rock was a leucite tephrite, and concluded that it was related to the Beemerville nephelite syenite.[6]

[1] H. S. Washington, *Jour. Franklin Inst.*, CXC (1920), p. 796.

[2] B. K. Emerson, *Amer. Jour. Sci.*, XXIII (1882), p. 302.

[3] *Ibid.*, p. 376.

[4] J. F. Kemp, *Amer. Jour. Sci.*, XXXVIII (1889), p. 130.

[5] J. F. Kemp, *Trans. N.Y. Acad. Sci.*, XI (1892), p. 60.

[6] J. F. Kemp, *Amer. Jour. Sci.*, XLV (1893), p. 303.

Kemp's material was studied by Hussak, who had no hesitation in terming the rock a leucite tephrite, and considered that the spheroidal pseudomorphs were pseudoleucite, or were at any rate pseudomorphs after leucite.[1] Kemp then visited some newly exposed dykes at Rudeville and obtained material which provided definite proof of the existence of leucite, and came to the conclusion that the "mica-diabase" dykes of Rudeville, Franklin Furnace, and the Hamburg dyke are all related to the Beemerville mass.[2] Kemp's papers are illustrated with useful locality maps, but the analyses given are all incomplete and inadequate.

A complete petrological description of the nephelite syenite of Beemerville and the large dyke at Franklin Furnace, together with good, though incomplete, analyses, is given by Iddings, who recognized the Franklin Furnace dyke to be a minette.[3]

In 1899 Ransome described a small occurrence of nephelite syenite, mica syenite, hornblende syenite, and hornblende granite, associated with Mesozoic gabbro, at Brookville, in Hunterdon County, New Jersey, sixty miles west of south from Beemerville. The relations of these rocks to the gabbro were not clearly ascertained, and they were regarded by Ransome as inclusions, though he considered the possibility of an intrusive relation.[4] Our colleague, Dr. N. L. Bowen, has collected specimens from this locality which suggest differentiation of the nephelite syenite and, on a small scale, an intrusive relation toward the gabbro.

In 1902 Wolff described an undoubted leucite tinguaite dyke, which cuts the Beemerville nephelite syenite mass near its southern end, giving a detailed account of the pseudoleucite, and a good and complete analysis of the rock. This is the most satisfactory existing analysis of any rock from the alkalic series of Sussex County.[5] Finally, in 1908 Wolff provided a co-ordinated description of the igneous rocks of Sussex County,[6] in which he points out that the same

[1] E. Hussak, *Neues Jahrbuch*, II (1892), p. 153.

[2] J. F. Kemp, *Amer. Jour. Sci.*, XLVII (1894), p. 339.

[3] J. P. Iddings, *U.S. Geol. Surv., Bull. 150* (1898), pp. 209 and 236.

[4] F. L. Ransome, *Amer. Jour. Sci.*, VIII (1899), p. 417.

[5] J. E. Wolff, *Bull. Mus. Comp. Zoöl. Harvard*, XXXVIII (1902), p. 273.

[6] J. E. Wolff, *Geol. Atlas, New Jersey*, Franklin Furnace folio (1908), p. 12.

pyroxene, a zoned aegirite-augite, and large crystals of titanite and biotite characterize nearly all the rocks of the series, and that the main nephelite syenite mass of Beemerville, with its transgressive dykes of nephelite porphyry and leucite tinguaite, has a definite relation to the disposition of other rocks of the series. Close to it, to the east and south, are the bosslike or necklike ouachitite breccias; farther to the southeast is a zone of nephelite syenite and bostonite dykes, which, like the main mass, are concordant with the bedding of the intruded series (the Ordovician Martinsburg shale); finally, at some distance to the southeast, are the lamprophyric dykes, which are disposed radially toward the Beemerville mass, intruding the Ordovician Kittatinny limestone and the pre-Cambrian Franklin limestone. Wolff concludes that the alkalic rocks are post-Devonian in age and probably much later.

THE NEPHELITE SYENITE OF THE BEEMERVILLE MASS

The main mass of nephelite syenite forms a long, narrow intrusion of elliptical outcrop, lying between the Silurian Shawangunk conglomerate and the Ordovician Martinsburg shale, at the foot of the Kittatinny Ridge, the southern extremity of the mass being two miles to the northwest of Beemerville. It is most easily accessible from the town of Sussex (formerly called Deckertown, and referred to by that name by Emerson and Kemp).

The formal relationships of the mass are obscure. Both Emerson and Kemp regarded it as a large dyke, but Wolff is inclined to regard it as a sill, or an irregular, flat laccolithic mass. Washington visited the locality in 1901 in company with Professors Kemp and Brögger, and is in agreement with Wolff's opinion. It was examined by Aurousseau in the summer of 1921, with special regard to this point, but no evidence of a decisive nature is obtainable on the ground. As the mass has been studied by a number of competent geologists at intervals over a long period of time, it is improbable that any fuller information will be forthcoming, the outcrops being poor and the contacts obscured by thick soil and drift. In particular, no variations of dip are to be observed in the massive Shawangunk conglomerate which overlies the mass. To our minds the occurrence of the body (which can hardly be younger than

early Tertiary and is probably much older) at the junction of the Shawangunk conglomerate and the Martinsburg shale, is critical, and, taken in conjunction with the fact that long, narrow intrusions of nephelite syenite and bostonite lie parallel to the bedding of the Martinsburg shale farther to the east, inclines us to the opinion that the Beemerville mass is a lenticular sill, or a flat laccolith.

The nephelite syenite is a somewhat basic foyaite, of the "foyaite range" as recently defined in the classification of the nephelite syenite family proposed by Shand.[1] It is very variable along the mass and, although the bulk of the exposure is a fairly constant foyaite of the Magnet Cove, Arkansas, or the Umptek type, it grades locally into other facies, which are often more basic than the main mass. Ditroitic and ijolitic modifications may be collected, and especially along the eastern border it becomes foliated, or lujavritic, in character. Near the center of the exposure, small, local facies with abundant titanite may be found. These variations have been admirably described by Emerson and by Kemp. Kemp's description may be quoted to illustrate this point:

> The dike varies considerably along its course. The typical elaeolite-syenite forms the northern third and the southern extremity, but between these points its character changes. Near the southern part of the middle third elaeolite-porphyry appears, and forms a most beautiful example of this rock. It may come from dikes, as no actual exposures are available. Further south a basic holocrystalline rock comes in which is exposed in place; and, as subsequently shown, contains less silica and more biotite than the typical syenite. But on the extreme south where the highway crosses the dike, the rock is much like that on the north. It is, however, greatly decomposed, and fresh, firm, pieces are hard to find.[2]

The variation, even of what appears to be the predominant rock, is well shown by comparing the analyses by Eakins and Aurousseau (Table I). The Martinsburg shale, along the eastern contact, has been metamorphosed to a hornstone, the aureole being narrow.

To the very complete petrographic description of the normal rock, given by Iddings, we have little to add. One slight correction is necessary. The mineral identified as sodalite belongs to the hauynite-noselite series, as is indicated by the analysis here given.

[1] S. J. Shand, *Trans. Geol. Soc. South Africa*, XXIV (1921), p. 117.

[2] J. F. Kemp, *Trans. N.Y. Acad. Sci.*, XI (1892), p. 64.

The most noteworthy chemical characters of the nephelite syenite are its low silica percentage, the approximate equality in amount of soda and potash, the high content of titanium and zirconium, and the comparatively large amount of SO_3 as compared with chlorine. Though it undoubtedly belongs to the highly sodic

TABLE I

	I	II	III	IV	V	
SiO_2	47.19	53.56	53.09	52.25	Z	0.18
Al_2O_3	23.01	24.43	21.16	22.24	Or	33.08
Fe_3O_2	3.11	2.19	1.89	2.42	An	6.39
FeO	2.23	1.22	2.04	1.98	Lc	11.99
MgO	1.07	0.31	0.32	0.96	Ne	32.66
CaO	2.93	1.24	3.30	1.54	Th	0.71
Na_2O	7.97	6.48	6.86	9.78	Nc	0.95
K_2O	8.23	9.50	8.42	6.13	Di	4.32
H_2O+	0.55	0.93	1.13	0.73	Ol	0.98
H_2O-	0.04		0.24		Mt	1.39
CO_2	0.38	....	0.82	....	Il	4.10
TiO_2	2.16	....	0.11	0.60	Hm	2.08
ZrO_2	0.13	....	0.04	....	Ap	1.01
P_2O_5	0.39	....	0.15	0.53	Water	0.59
SO_3	0.45	....	None	....	....	....
Cl	0.01	....	0.02	....	....	....
F	p.n.d.	....	....	....	....	....
S	....	....	0.08	....	....	....
Cr_2O_3	None	....	....	....	....	....
$(CeY)_2O_3$	0.06	....	....	....	....	....
MnO	0.16	0.10	0.20	....	....	....
BaO	0.09	....	0.61	....	....	....
Sum	100.16	99.96	100.48	99.16	....	100.43

I. Nephelite syenite, Beemerville, N.J. M. Aurousseau, anal.

II. Nephelite syenite, Beemerville, N.J. L. G. Eakins, anal. *U.S. Geol. Surv. Bull. 150* (1898), p. 211.

III. Foyaite, Magnet Cove, Ark. H. S. Washington, anal. *Jour. Geol.*, IX (1901), p. 611.

IV. Lujavrite, Rabots Spitze, Kola. V. Hackmann, anal. *Fennia*, XI (1894), p. 132.

V. Norm of I. Symbols, (I) II. 7. 1'. 3. Janeirose.

comagmatic region of the eastern United States, in these respects it differs remarkably from the well-known nephelite syenites of Massachusetts, Connecticut, New Hampshire, and Maine, and also from the nearest similar exposure, that is, from the nephelite syenite of Brookville. The last-named rock resembles the nephelite syenites of New England and shows the essential differences between them and the Beemerville rock (see Table III). The other nephelite syenites of the northeastern United States, and, in

general, those of eastern Canada, are characteristically dosodic, contain less titanium, and where it has been determined, less zirconium than that of Beemerville: they are also more silicic, and some of the Canadian rocks have a marked tendency to show an excess of alumina. The material analyzed by Eakins is termed "the average rock" by Iddings. That used for the analysis here presented was

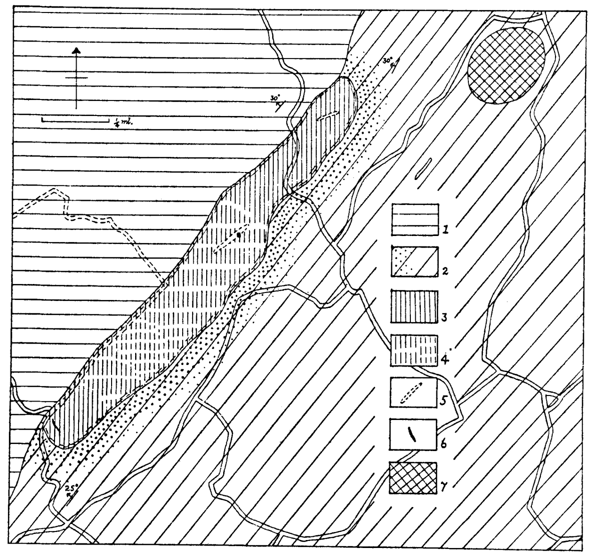

FIG. 1.—The *character* of the Beemerville intrusion, as inferred from the distribution of rock types: (1) Shawangunk conglomerate. (2) Martinsburg shale and contact aureole. (3) Normal nephelite syenite, with occasional nepheline-rich, and lujavritic (marginal) facies. (4) Transition of normal nephelite syenite into darker variety with biotite and titanite. (5) Nephelite porphyry, with tinguaitic and sussexitic facies. (6) Leucite tinguaite. (7) Ouachitite breccia of Rutan's Hill. Diagram partly idealized. Main boundaries from the Franklin Furnace folio. The probable occurrence of a dyke of nephelite porphyry in the northern part of the main mass is suggested by an observation of Emerson, *Amer. Jour. Sci.*, XXIII (1882), p. 308.

collected by Dr. Wolff and is representative of the northern third and the southern extremity of the mass. The non-determination of TiO_2 and P_2O_5 by Eakins of course affects the figures for Al_2O_3.

As has been stated already, the Beemerville nephelite syenite resembles most closely the foyaite of Magnet Cove, Arkansas. An analysis of the latter rock is given in Table I for comparison together with a lujavrite from Umptek, described by Hackmann. The Arkansas rocks are characteristically sodi-potassic, like those

of the Beemerville, though slightly more silicic. The most noteworthy differences are in the titanium and zirconium, and in the ferrous-ferric relationships. The Arkansas syenite apparently contains less of the acmite and more of the diopside molecule than that of Beemerville, and is distinctly poorer in titanium and zirconium. The minor differences among the volatile constituents also are not without interest.

THE NEPHELITE PORPHYRY

The nephelite porphyry, referred to in Kemp's description of the variations of the main mass, is not exposed in a way which permits of a determination of its relationships. It is found in the neighborhood of Mr. T. Conroy's house, near the middle of the main mass, and specimens have been collected from the north of the house, and from the peach orchard southwest of the house. Again quoting from Kemp:

> At the middle of point 4 C on the map the character of the dike changes, as is indicated by the float fragments, for no actual exposures occur. Porphyritic facies appear, and an excellent elaeolite porphyry was found. . . . . Another porphyritic rock occurs along this portion of the dike, which lacks the large phenocrysts of elaeolite. It has, however, others of feldspar, and in the slide shows the same tinguaitic base with a much more prismatic development of the elaeolite in the groundmass.[1]

A small dyke of the same rock occurs two miles northwest of the town of Sussex, and is shown on the map of the Franklin Furnace folio. The nephelite porphyry of the main mass of Beemerville does not reveal its contacts. We believe it to be a dyke of some size, intruding the main mass, and both coarse- (definitely porphyritic) and fine-grained modifications, the latter suggestive of marginal relationship, may be collected north of Mr. Conroy's house.

The rock is typically porphyritic with nephelite crystals, and occasionally with orthoclase. In one specimen small phenocrysts of blue fluorite are quite visible to the naked eye. The groundmass, which has the typical, dull-green color of the tinguaites, is variable in texture in different specimens, and in the finer-grained variety consists of a mosaic of interlocking grains of orthoclase and nephelite, penetrated by minute aegirites. In the more normal variety the aegirites exist in two generations, those of the groundmass forming

[1] J. F. Kemp, *Trans. N.Y. Acad. Sci.*, XI (1892), pp. 66–67.

minute tufts. Orthoclase also shows its twinned development here. The larger aegirites are associated with small but numerous crystals of titanite and a little biotite. A few patches of ilmenite are noticeable, and under high power a little perovskite and apatite may be seen. Cancrinite and hauynite are quite minor constituents, and there is very little development of carbonates. The general mineralogical development is quite similar, except as regards texture, to that of the nephelite syenite itself. Though orthoclase exists in minor amount in some cases, ordinarily it is an important constituent.

TABLE II

	I	II	III	IV	V	VI	VII	VIII	
SiO_2....	50.08	49.84	49.96	55.31	45.64	50.16	46.48	Z	0.32
Al_2O_3...	17.64	19.47	19.23	21.74	19.50	19.75	19.00	Or	41.14
Fe_2O_3...	4.70	4.40	4.55	1.77	3.47	4.28	4.74	Ab	4.19
FeO....	2.27	2.24	2.26	1.02	3.34	3.62	2.30	Ne	30.10
MgO....	1.12	1.34	1.23	0.47	3.04	1.12	2.49	Hl	0.12
CaO....	3.96	4.35	4.15	1.57	4.45	3.10	4.35	Th	0.71
Na_2O...	8.10	8.07	8.08	8.77	11.57	7.63	8.46	Nc	0.32
K_2O....	7.30	6.71	7.01	6.49	6.96	6.73	6.78	Ac	3.70
H_2O+..	....	0.38	0.38	1.94	0.16	3.96	3.31	Di	6.70
H_2O-..	0.06	....	0.06						
CO_2....	....	0.12	0.12	0.11	....	....	0.36	Wo	3.71
TiO_2....	1.75	1.27	1.51	0.07	2.44	....	1.22	Mt	3.48
ZrO_2....	....	0.16	0.16	....	....	....	....	Il	2.89
P_2O_5....	0.54	....	0.54	Tr.	....	0.13	0.15	Hm	0.80
SO_3....	0.39	....	0.39	....	....	....	0.19	Ap	1.34
Cl.....	....	0.04	0.04	0.60	....	....	0.08	Water	0.44
F.......	....	....	p.n.d.	....	....	....	....	....	....
Cr_2O_3...	....	None	None	....	....	....	....	....	....
$(CeY)_2O_3$	....	0.05	0.05	....	....	....	....	....	....
MnO...	0.17	....	0.17	....	0.19	....	Tr.	....	....
BaO....	0.32	....	0.32	....	....	....	....	....	....
Sum..	....	....	100.21	99.86	100.76	100.48	99.91	....	99.96
Less O	....	....	0.01	0.13	....	....	0.02	....	....
Sum..	....	....	100.20	99.73	100.76	100.48	99.89	....	....

I. Nephelite porphyry, Beemerville, N.J. H. S. Washington, anal. Incomplete.
II. Nephelite porphyry, Beemerville, N.J. M. Aurousseau, anal. Incomplete.
III. Average(excluding Al_2O_3 of I) of I and II.
IV. Tinguaite, Monte Mulatto, Predazzo, Tyrol. M. Dittrich, anal. J. Romberg, *Sitzb. Preuss. Akad. Wiss.*, I (1902), p. 748.
V. Nephelite porphyry, Wudjavrtschorr, Upmtek, Kola. V. Hackmann, anal. V. Hackmann, *Fennia*, XI (1894), p. 151.
VI. Tinguaite, Hooper's Inlet, Dunedin, New Zealand. P. Marshall, anal. P. Marshall, *Quar. Jour. Geol. Soc.*, XLII (1906), p. 396.
VII. Leucitite, Etinde Volcano, Kamerun. M. Dittrich, anal. *Sitzb. Preuss. Akad. Wiss.* (1901), p. 299.
VIII. Norm of III. Symbols, II. (6) 7. 1. 3. Janeirose.

Chemically the rock is a foyaite and differs in no essential manner from the nephelite syenite. Indeed, the similarity of the analyses of the nephelite syenite and of the nephelite porphyry is remarkably striking. The latter contains less alumina and titanium than the former, but is a very close parallel to it otherwise. What has been said, therefore, of the affinities of the nephelite syenite applies likewise to the nephelite porphyry. The specimen analyzed was selected with care, and comes from the neighborhood of the peach orchard mentioned. It is, as nearly as possible, the average porphyry.

The rock was analyzed independently by each of us. As the summation from Washington's figures was low, and inspection showed that the figures for alumina were probably at fault, the average of the two analyses was taken, excluding the alumina from I, and correcting that of II only by the deduction from it of one-half of the difference between the two determinations of TiO_2. Column III represents the accepted values. On comparing the rock with others of a similar nature, it is seen that it resembles the nephelite porphyries of other localities. In particular may be mentioned the nephelite porphyry of Julianehaab[1] (Fox Bay type), which is very different mineralogically, however, and the nephelite syenite porphyry of the Val dei Coccoletti, in the Tyrol.[2] The last-named rock is practically the chemical equivalent of the tinguaite of Monte Mulatto, Predazzo, and indeed, so great is the chemical resemblance of the Beemerville nephelite porphyry to certain tinguaitic and leucitic rocks, that we quote the tinguaite of Monte Mulatto (IV of Table II) in preference to the nephelite porphyry. Column V is the nephelite porphyry of Umptek, a more sodic rock, but otherwise similar; while VI and VII are respectively the tinguaite of Hooper's Inlet, Dunedin, New Zealand, and a leucitite from Kamerun. The similarity in chemical composition between the Beemerville magma and the magma which has produced the richly leucitic leucite phonolite of Poggio Muratella, Lake Bracciano, has already been pointed out elsewhere.[3] We desire to stress the simi-

[1] N. V. Ussing, *Geol. Julianehaab, Meddel. om Grönld.*, XXXVIII (1911), p. 275.

[2] J. Romberg, *Sitzb., Preuss. Akad. Wiss.*, I (1911), p. 748.

[3] H. S. Washington, *The Roman Comagmatic Region* (1906), p. 47.

larity of the nephelite porphyry of Beemerville to other nephelite porphyries and similar rocks, because the Beemerville rock, on the basis of a poor analysis, was made the type of the species sussexite. This matter will be discussed below.

CRYSTALLIZATION VARIANTS OF THE BEEMERVILLE MAGMA

The nephelite porphyry and the leucite tinguaite described by Wolff occur within the main mass of nephelite syenite. We believe the first to be a dyke of some magnitude, while the second is a dyke only fifteen inches wide. The leucite tinguaite, also, differs from the nephelite syenite in no other way than in the reversal of the ferrous-ferric relation and a change in the rôle of sulphur (see II of Table III below). The main mass crystallized completely as orthoclase, nephelite, and aegirite. The smaller mass (dyke?) of nephelite porphyry is only a textural variant of the same magma, while the smallest dyke, of the same chemical composition, is a mineralogical variant, having produced a certain amount of leucite and little or no primary orthoclase. The symbols of the three rocks indicate clearly that there has been no chemical differentiation. They are as follows:

$$\left.\begin{array}{l}\text{Nephelite syenite, Beemerville, (I) II.7.1}'\text{.3.}\\ \text{Nephelite porphyry, Beemerville, II.(6)7.1.3.}\\ \text{Leucite tinguaite, Beemerville, II.7(8).1.3.}\end{array}\right\}\text{Janeirose}$$

They all fall in the same subrang. It may be mentioned here that the subrang Beemerose was established from Eakin's analysis, which does not seem to be so representative of the mass as the new analysis here presented. The crystallization variants appear to be due to differences in the rates of cooling of the three rocks, an assumption based upon the respective volumes of the masses concerned. That a nephelite syenite magma is capable of producing leucitic rock is a matter of great interest, and the presence of nearly 12 per cent of leucite in the norm of the Beemerville nephelite syenite may be significant in this respect. The great similarity of the Beemerville magma to certain tinguaites, as already mentioned, is a matter of like nature, that is, the expression of magmas of similar composition in feldspathic and feldspathoid form. In view of some results obtained by Morey and Bowen, on the thermal

relations of leucite and orthoclase,[1] there is no difficulty in accepting the leucite tinguaite of Beemerville as the rapidly cooled equivalent of the nephelite syenite. This interpretation also tends to confirm Kemp's diagnosis of leucite in the true differentiates of the magma, the dykes at Rudeville and Hamburg.

THE OCCURRENCE OF ZIRCONIA AND RARE EARTHS

In the Beemerville rocks the amount of zirconia is rather high. This illustrates the fact that the region east of the Appalachians, from Essex County Massachusetts, through New Jersey as far as North Carolina, and possibly beyond, is a region rich in zirconia. Numerous localities for zircon have been discovered in New Jersey (personal communication from Dr. J. E. Wolff), and its distribution, and that of the rare earths in places, is so well known in Virginia and North Carolina as to need no great comment here. The zirconia is not necessarily confined to sodic rocks, and indeed most frequently occurs in zircon pegmatites, like the well-known pegmatite at Tuxedo, near Hendersonville, North Carolina. The rare earths occur mostly in allanite, which has a fairly wide distribution in Maryland and Virginia. Our determination of the rare earths in the nephelite syenite and nephelite porphyry is the first record of them in northern New Jersey. A number of unpublished analyses of aegirites, by Washington, indicate that the rare earths of the Beemerville rocks occur in the aegirite. The bulk of the rare earth precipitates in our analyses was too small to admit of any separation being made, but the chemical behavior during the determinations suggests that yttrium preponderates over cerium, and that thorium is present.

As the literature of the alkalic rocks of northern New Jersey is scattered, and in part somewhat old, we append the superior analyses of other rocks of the district, with which we have not dealt directly here. We have included an inferior analysis of the ouachitite of Rutan's Hill, by Kemp, as there is no other chemical information extant concerning the basic lamprophyres. The summation of this analysis is low, in spite of the fact that the iron is all expressed as Fe_2O_3, and the water and CO_2 are merely repre-

[1] G. W. Morey and N. L. Bowen, *Amer. Jour. Sci.*, IV (1922), p. 1.

sented as "loss on ignition." As regards the other analyses of the table, the MnO of II is probably too high, and the non-determination of P_2O_5 and TiO_2 in III of course render the figures for alumina too high. All other analyses of the alkalic igneous rocks from this region we have discarded as unfit for use.

TABLE III

	I	II	III	IV
SiO_2	54.68	50.00	40.71	40.47
Al_2O_3	21.63	20.03	19.46	11.86
Fe_2O_3	2.22	0.98	7.46	17.44
FeO	2.00	3.98	6.83	
MgO	1.25	0.69	6.21	3.10
CaO	2.86	3.41	11.83	16.80
Na_2O	7.03	8.28	1.80	1.90
K_2O	4.58	8.44	3.26	4.21
H_2O+	1.88	1.50	1.53	3.60
H_2O-	0.27	0.10		
CO_2	None	0.22	0.74	....
TiO_2	0.79	0.99	....	....
P_2O_5	0.28	0.21	....	....
SO_3	0.07	....	....	....
Cl	None	Tr.	....	....
F	0.22	n.d.	....	....
FeS_2	....	0.54	....	....
MnO	Tr.	0.50	0.18	....
BaO	0.05	None	....	....
Sum	99.81	99.87	100.01	99.38
Less O	0.09	....	....	....
Sum	99.72	99.87	100.01	99.38

I. Nephelite syenite, Brookville, Hunterdon Co., N.J. G. Steiger, anal. *Amer. Jour. Sci.*, VIII (1899), p. 423.

II. Leucite tinguaite, Beemerville, N.J. J. E. Wolff, anal. *Bull. Mus. Comp. Zoöl. Harvard*, XXXVIII (1902), p. 276.

III. Minette, Franklin Furnace, N.J. L. G. Eakins, anal. *U.S. Geol. Surv. Bull. 150* (1898), p. 238.

IV. Ouachitite, Rutan's Hill, Beemerville, N.J. J. F. Kemp, anal. *Amer. Jour. Sci.*, XXXVIII (1889), p. 133.

THE STATUS OF SUSSEXITE

Brögger, in working out the grorudite-tinguaite suite of the Kristianiagebiet, extrapolated from his analyses of the series, and calculated an end member for the suite, the composition of which is shown in column II of Table IV. No rock corresponding to this hypothetical composition was found in the Kristianiagebiet,

but Brögger considered that Kemp's analysis of the Beemerville nephelite porphyry, together with the description, indicated that a rock of the hypothetical, calculated composition, and corresponding to an end member of this series, actually existed. He therefore defined the species now known as *sussexite*,[1] making the Beemerville rock the type, in the following terms:

> Gesteine wie diejenigen von Beemerville waren aber früher nur wenige bekannt, jedenfalls nur wenige analysirt; sie bilden einen ganz distincten chemischen Typus, wie sie auch geognostisch durch ihre häufige Verknüpfung mit Nephelinsyeniten charakterisirt sind; dementsprechend sind sie reich an Alkalien, arm an Kalk und Magnesia und mässig reich an Eisenoxyden, aber mit sehr hohem Al_2O_3 Gehalt. Es wäre entschieden irreleitend, diese Gesteine als Nephelinite zu bezeichnen, nur deshalb weil sie aus Nephelin (und Aegirin) bestehen.

A sussexite, according to Brögger's definition, is a nephelite porphyry either poor or lacking in orthoclase, and therefore a persodic or dosodic rock, resembling the urtites and ijolites in composition.

TABLE IV

	I	II	III
SiO_2	45.18	45.0	47.43
Al_2O_3	23.31	25.0	23.60
Fe_2O_3	6.11	6.5	4.59
FeO			1.20
MgO	1.45	1.5	1.20
CaO	4.62	2.0	0.67
Na_2O	11.16	12.0	15.08
K_2O	5.95	7.0	2.00
H_2O	1.14	1.0	....
TiO_2	....	....	0.10
Sum	98.92	100.0	99.09

I. Nephelinitic facies of nephelite porphyry, Beemerville, N.J. J. F. Kemp, anal.(?) J. F. Kemp, *Trans. N.Y. Acad. Sci.*, XI (1892), p. 67. Brögger's type for the species Sussexite.

II. Hypothetical Sussexite, calculated by extrapolation from the Grorudite-Tinguaite series. W. C. Brögger, *Eruptivgest. des Kristianiagebietes*, I (1894), p. 172.

III. Sussexite, Penikkavaara, Kuusamo, Finland. M. Dittrich, anal. V. Hackmann, *Bull. Comm. Géol. Finlande*, XI (1900), p. 22.

Kemp's analysis (see I of Table IV) indicates that the sample he analyzed corresponded fairly closely to Brögger's definition of

[1] W. C. Brögger, *Eruptivgest. des Kristianiageb.*, I (1894), p. 173.

the type. It is certainly dosodic. We have shown here that the nephelite porphyry of Beemerville is a sodipotassic rock, in no important respect different from other nephelite porphyries, and we can only conclude that the sample chosen for analysis by Kemp was not representative. Kemp's own descriptions of the nephelite porphyry show that the rock he described was not abnormally poor in orthoclase. Consequently the Beemerville rock cannot maintain its position as the type sussexite. Only one rock corresponding to Brögger's original definition has been analyzed so far, it being the sussexite of Kuusamo, Finland, described by Hackmann (see III of Table IV). As it establishes the existence of the species (the existence of which may be said to have been predicted by Brögger), the name sussexite should remain in use, in the sense of Brögger's definition. Sussexite is essentially a nephelite porphyry devoid of feldspar, or, in other words, a porphyritic urtite.

Rocks of the nephelite syenite family tend to lack homogeneity within the mass, and too much care cannot be exercised in the selection of material for analysis, which will correspond well with the material upon which the petrographic descriptions are based. Another instance showing lack of correspondence between the chemical analysis and the mineralogical description is the mariupolite described by Morozewicz.[1] The analysis of this rock does not permit of the existence of the amount of nephelite it is said to contain (according to the description).

The Beemerville nephelite porphyry has been widely accepted as the type of sussexite. Iddings calculated the ratio

$$\frac{Na_2O+K_2O}{SiO_2}$$

for Brögger's grorudite-tinguaite series and found that the Beemerville rock, from Kemp's figures, lay upon a prolongation of the approximately straight line representing the series in the diagram.[2] The Beemerville rock, however, is not a differentiate at all, but, as we have shown, a textural variant of the main mass of the nephelite syenite.

[1] J. Morozewicz, *TMPM*, XXI (1902), p. 230.

[2] J. P. Iddings, *Jour. Geol.*, III (1895), p. 357.

SUMMARY

The scattered contributions to the geology and petrology of the alkalic igneous rocks of northern New Jersey are reviewed in chronological order, and a general account of these rocks is given.

The large mass of nephelite syenite northwest of Beemerville is described and is interpreted as a lenticular sill or a flat laccolith of foyaite, intruded by a mass of nephelite porphyry (probably a dyke) and by a small dyke of leucite tinguaite.

New analyses of the nephelite syenite (foyaite) and of the nephelite porphyry are presented, and the affinities of these rocks and of the leucite tinguaite are discussed. It is concluded that these three rocks are textural and mineral variants, without chemical differentiation, of the same magma.

It is shown that the nephelite porphyry is not a sussexite, as formerly supposed, and the status of sussexite as a rock variety is considered, with the conclusion that the name should be retained in its original sense, but that the nephelite porphyry of Beemerville can no longer be regarded as the type of the variety.

The presence of zirconium and the rare earths in the Beemerville rocks has been demonstrated, and the wide distribution of these elements in the region east of the Appalachians is briefly discussed.

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